Novel Ignition Promoter for Investigation of the High-pressure Oxygen Generator Assembly Fire-containment Capability

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The possibility of a fire within a high-pressure oxygen generator assembly (HPOGA) creates critical safety issues when the HPOGA is to be used on the International Space Station. An investigation was therefore needed to determine whether a properly designed, constructed, equipped, and aligned HPOGA could contain a fire indefinitely, preventing an over-board pressure release from endangering lives and causing catastrophic structural failure.

The HPOGA is a high differential pressure cell stack assembly consisting of a hydrogen end assembly, an oxygen end assembly, and alternating layers or bipolar plate assemblies as well as membrane and electrode assemblies sandwiched between a stack compression system. The stack compression system maintains sufficient compressive load on the cell stack hardware to ensure the mechanical and electrical integrity of the assembly is maintained up to the maximum design operating pressure of 3000 psig. Personnel at NASA's White Sands Test Facility constructed several mock-ups of varying fidelity, including a complete HPOGA, in order to study the ability of an HPOGA wall to contain a fire (figure 1). This would either validate or disprove the hypothesis that the oxygen inventory was sufficiently limited to ensure that a membrane breach-initiated fire would extinguish before a burnout could occur.

Arc starting is a convenient way to ignite metals because measurement of the deposited energy is simple and accurate. Two mock-up test articles were manufactured for the testing process to develop an appropriate electrical arc ignition method to initiate a fire at the pressure containment wall in high-pressure oxygen. The design allowed for electrical arc current to be delivered through a stainless steel probe with a niobium tip to the inner wall of the niobium foil laminate assembly shown as the porous plate frame in figure 1.

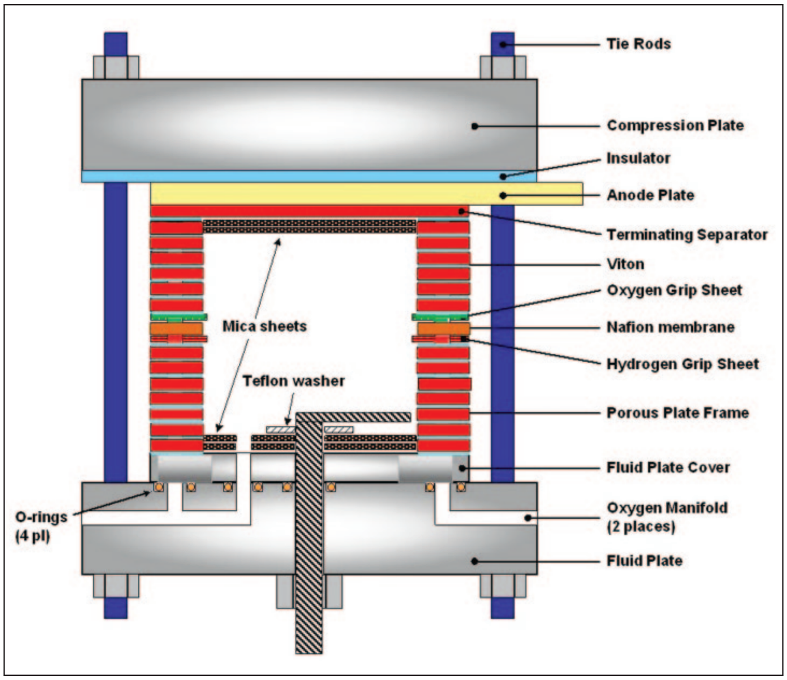

Fig. 1. *Test article to be ignited inside by welder arc.*

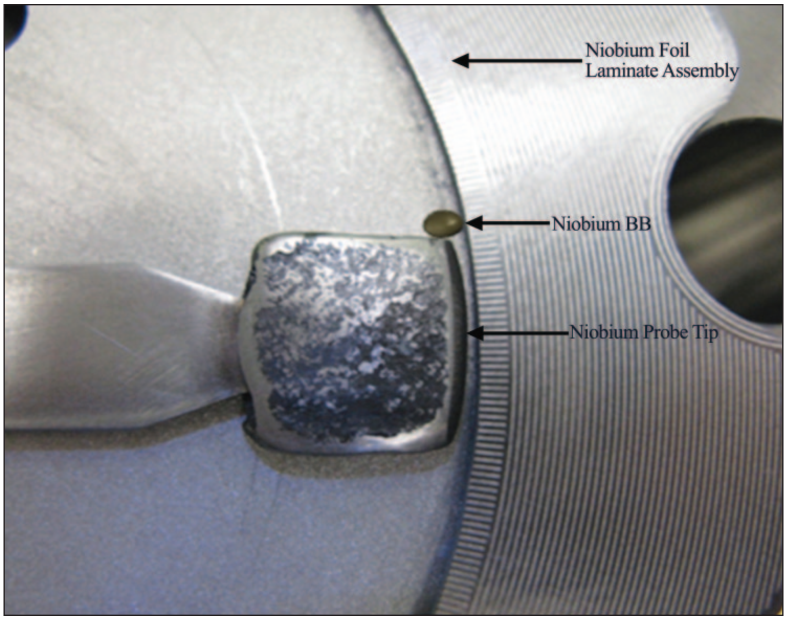

Fig. 2. *Niobium BBs added to bridge the arc gap.*

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continued

During checkout testing, researchers discovered that the insulating properties of high-pressure oxygen were greater than anticipated. While the high-frequency generator was able to pierce oxide coatings in 3000-psig oxygen, it was unable to produce a sufficient overvoltage to allow an arc to be established across the 1.5-mm gap to the laminate assembly. After numerous unsuccessful attempts to adjust the intensity of the high-frequency arc, oxygen pressure was reduced incrementally to determine the breakdown threshold. Arc initiation in oxygen occurred only below a pressure of 200 psig. Above 200 psig, the arc would not jump the gap. A solid niobium BB was applied to the test article to reduce the gap between the probe and the cell frames, but this proved inconsistent at establishing the electrical arc at the wall of the laminate assembly (figure 2). A BB-sized piece of fine niobium turnings was used next. That niobium wool was ignited and had the power to kindle to the niobium probe tip and the laminate assembly (figure 3).

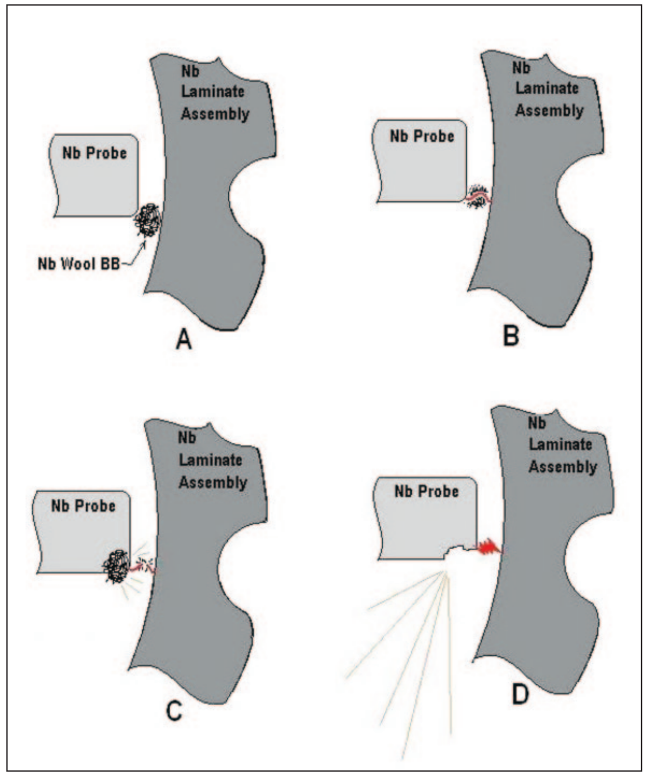

Fig. 3. Sequence of fire propagation in test series.

Conclusions

High-pressure oxygen is an efficient electrical insulator. When the oxygen pressure is more than 200 psig, arcs could not be initiated using a high-frequency arc starter alone. A combination of niobium wool and a high-frequency start was necessary to initiate a fire in the probe tip and laminate assembly.

The selection of niobium to make the wool did not change the combustion chemistry of the niobium probe tip or the laminate assembly.

The NASA Johnson Space Center's White Sands Test Facility mock-up provided a reasonable simulation of a fire in a real HPOGA unit because the niobium wool approximated the density of the porous niobium supports used in a true HPOGA.